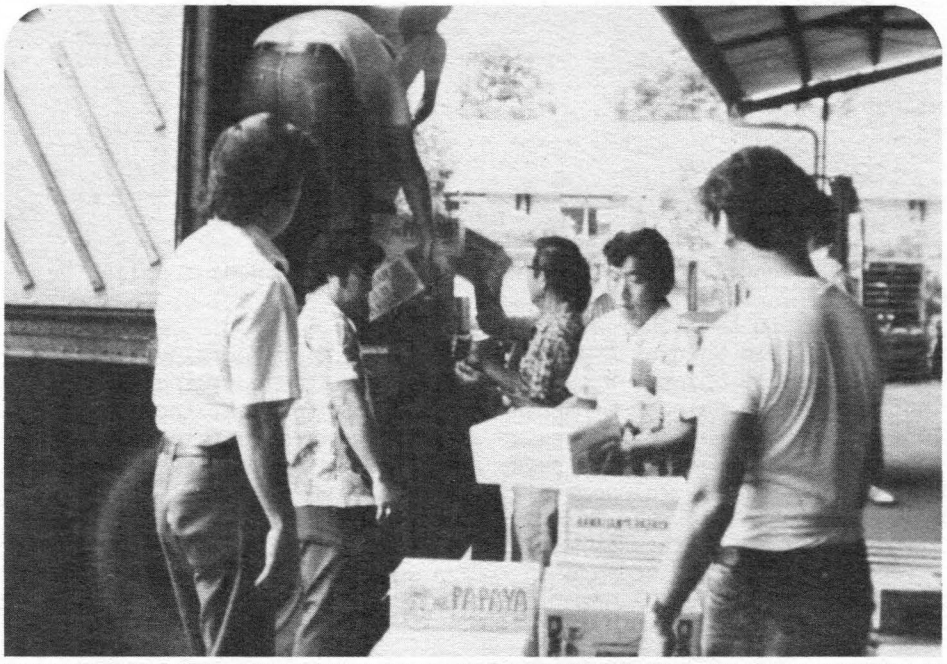
Simulated Hawaii Papaya Surface Shipping Test

Ernest K. Akamine and Theodore Goo



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On the cover:
Top, loading container with Hawaii papayas; *bottom*, making daily observations on shelf life of Hawaii papayas after removal from container.

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ACKNOWLEDGMENTS

The cooperation and assistance of the papaya shippers, government agencies, and a shipping firm, which were involved in this investigation, are acknowledged with appreciation. The Hawaii County Department of Research and Development recommended this investigation, and Mr. Yoshio Watanabe of this agency effectively coordinated the various phases of this undertaking. Five papaya shipping companies--Diamond Head, Aloha Papaya Co., Puna Papaya Co., Ono Pac, and Mr. Papaya--supplied fresh papayas, helped with the loading and unloading of the container, and assisted in evaluating shelf life of the fruits after removal from the container. Matson Navigation Co. provided the use of a shipping container for this study. Puna Papaya Co. provided transportation to move the container to and from the premises of Aloha Papaya Co. In addition to providing a power outlet and parking space for the container, Aloha Papaya Co. provided a room where the papayas were held during the observation period. Mr. Warren Ikeda of the Hawaii Cooperative Extension Service, Hilo, assisted with the daily data taking while the papayas were held in storage after removal from the container.

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Currently, nearly all fresh Hawaii papayas are shipped by air to the Mainland United States, Japan, and other market areas. In the last 2 years, cost of air shipment has drastically increased--up to more than 50%, and if air shipping costs continue to rise, as is anticipated, soon it will probably not be economically feasible to ship papayas by air.

Between 1959 and 1962, test shipments of Hawaii papayas to the West Coast of the United States using air and surface transportation were conducted as part of cooperative research by the Hawaii Agricultural Experiment Station, U.S. Federal and then Territory of Hawaii agricultural agencies, air and steamship companies, fruit handlers, and the papaya industry (Akamine et al., 1963). In surface transportation, papayas were shipped in reefers (cold rooms) or in refrigerated containers carried on board. The results indicated that air shipment was superior to surface shipment in terms of maintenance of quality and shelf life, but surface shipment using refrigerated containers was found to be feasible.

In 1975, the papaya industry again requested a study on the feasibility of shipping papayas by surface transportation because the differential between air and surface transportation costs had increased severalfold. This paper is a report on a simulated surface papaya shipment test conducted in Hilo, Hawaii.

PROCEDURE

A stationary, commercial, refrigerated Matson Navigation Co. container (8 ft x 24 ft) simulated surface shipment of papayas, except for the motion that uniquely occurs on a ship. Papaya fruits were provided by five shippers, designated here as Shippers A, B, C, D, and E.

Each shipper was requested to supply 30 cartons each of Hawaii Fancy or Hawaii No. 1 export grade, 1/4-ripe and 1/2-ripe, fruits for the purpose of experimental data collection. One shipper also supplied 5 cartons of 3/4-ripe fruits. Additionally, each shipper was requested to supply a proportionate number of filler cartons with reject fruits (unmarketable due to injury, size, shape, or maturity deficiencies) to be used to fill the balance of the container space. The number of experimental cartons per lot--in each stage of fruit ripeness of each shipper--varied from 5 to 30, and the number of fruits per carton varied from 8 to 12, depending on the size of the fruit. The total number of fruits per lot varied from 51 to 360 (Table 1). Each shipper used his own brand commercial carton presently used for air shipment, and the size of the carton (about 6-1/2 inches x 10-1/2 inches x 14 inches) was about the same for all brands.

Table 1. Experimental cartons and fruits of different stages of ripeness supplied by each shipper

Shipper	1/4-ripe fruit		1/2-ripe fruit		3/4-ripe fruit	
	No. of cartons	No. of fruits	No. of cartons	No. of fruits	No. of cartons	No. of fruits
A	29	347	30	360		
B	30	269	30	287		
C	30	240	30	240		
D	11	101	30	280	5	51
E	26	258	27	271		

Table 2. Fruit handling prior to container storage

Shipper	Disinfestation treatment[a]	Packing material[b]	Days of precooling[c]	Age of fruit on entry to container (days)[d]
A	Standard	Shredded newspaper	1,2,5,6,7	2,3,6,7,8
B	Vapor heat + Alternate	Plastic fruit separator	2,3	3,4
C	Standard	Plastic fruit separator	1	2
D	Alternate	Shredded newspaper	1	2
E	Standard	Shredded newspaper	13	14

[a]Standard treatment: hot water at 120°F for 20 min. + ethylene dibromide (EDB) fumigation at 1/2 lb/1000 cubic ft for 2 hr. Alternate treatment: EDB fumigation at 1 lb/1000 cubic ft for 2 hr. (If any treatment other than hot water is used, this EDB dosage is required.) Data on the actual temperatures of the hot water and vapor heat treatments as used by the shippers were not available.

[b]In sealed, standard, papaya carton.

[c]At about 50°F immediately after treating and packing.

[d]One day of holding after harvest + number of days of precooling: i.e., days from harvest to placement in container.

Shippers treated and packed their fruits according to their individual commercial practices. Thus, for disinfesting the fruit, three shippers used the standard treatment (hot water dip + 1/2 lb ethylene dibromide (EDB) fumigation per 1000 cubic ft space for 2 hr), one used the alternate treatment (1 lb EDB fumigation per 1000 cubic ft space for 2 hr), and one combined vapor heat with the alternate treatment. For packing the fruits, three shippers used shredded newspaper and two used plastic fruit separators. All cartons were sealed with sealing tapes to conform with quarantine regulations for export papayas. All fruits were treated and packed 1 day after harvest and then "precooled"[1] (about 50°F) for 1 to 13 days in the shippers' facilities before installing in the test. These and other pertinent data are summarized in Table 2.

The precooled cartons were loaded by hand into the container on January 22, 1976. The experimental and filler cartons of each shipper were located at random throughout the container. Filler cartons were used to record temperatures inside the cartons and fruits, one carton representing each of ten different positions in the container. A recording thermometer replaced one fruit in the carton, and a fruit thermometer was inserted into the cavity through the blossom end of one of the remaining fruits. To assure a uniform temperature distribution to the fruits, cartons were stacked (eight high) and spaced to provide good air circulation. A total of 1058 cartons was loaded into the container, and the temperature control was set for 50°F within the container.

On February 2, 1976 (after 11 days of simulated shipment), the cartons were removed from the container. The papayas in the filler cartons were discarded, and those in the experimental cartons were held at room temperature (65-79°F) for daily observations under simulated market-shelf conditions. Upon removal from the container and daily thereafter, the papayas were examined and those fruits judged unmarketable, due to decay or overripening, were recorded and discarded. Fruits that were both decayed and overripe were scored for decay only, because decay affects shelf life more significantly than overripening. Observations were made for 10 days.

[1]The papayas in this investigation were slowly cooled by storage in conventional cold rooms, and the term "precooling" is used here to indicate only that they were cooled prior to installing in the experiment and because this is the understanding of the term by local fruit handlers. Technically, however, the term is applicable only to special rapid-cooling procedures (vacuum cooling, hydrocooling, and air cooling) in which the field heat of a fresh commodity is rapidly removed after harvest.

RESULTS

Although the temperature control on the container was set for 50°F, the chart on the container recorded 51°F throughout the 11-day simulated shipping period. The carton temperature became 52°F 24 hours after the container was closed and ranged from 50 to 52°F during the remainder of the shipping period. The fruit temperature at the time the cartons were removed from the container ranged from 51 to 52°F. These temperature data indicated that air circulation within the chamber was adequate and that the carton loading and stacking method provided a uniform distribution of temperature for the fruits.

The results of the daily observations during the holding period are recorded in Tables 3, 4, 5, 6, and 7 for the papayas from individual shippers, and the percentage of marketable fruits is shown in Figures 1 and 2 for 1/4- and 1/2-ripe stages only. In general, for the 1/4-ripe fruits, Shipper A papayas had the highest daily percentage of marketable fruits, followed in decreasing order by Shipper C papayas, Shipper B and Shipper E papayas (equal to each other), and Shipper D papayas. For the 1/2-ripe fruits, the order was slightly altered in that Shipper D papayas and Shipper B and Shipper E papayas (equal to each other) exchanged places. The data also indicated that decay determines marketability of fruit in storage much more significantly than overripening (Tables 3, 4, 5, 6, 7).

Table 3. Daily percent marketable Shipper A papayas after simulated container-shipping, as determined by incidence of storage decay and overripening (data based on total number of fruits in each lot)

	1/4-ripe fruit			1/2-ripe fruit		
Days[a]	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable
0	2.3	0.0	97.7	2.4	0.0	97.5
1	3.5	0.0	96.5	4.4	0.0	95.6
2	5.8	0.0	94.2	9.2	0.0	90.8
3	8.9	0.0	91.1	19.7	0.0	80.3
4	24.8	0.0	75.2	43.6	0.0	56.4
5	38.3	0.0	61.7	58.9	0.0	41.1
6	50.4	0.0	49.6	66.4	0.0	33.6
7	61.3	0.9	37.8	74.0	6.1	19.9
8	69.7	5.2	25.1	81.4	8.6	10.0
9	76.1	8.6	15.3	83.0	13.1	3.9
10	81.0	11.5	7.5	83.6	13.9	2.5

[a]After removal from container. 0 = day removed.

Table 4. Daily percent marketable Shipper B papayas after simulated container-shipping, as determined by incidence of storage decay and overripening (data based on total number of fruits in each lot)

	1/4-ripe fruit			1/2-ripe fruit		
Days[a]	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable
0	12.3	0.0	87.7	24.0	0.0	76.0
1	14.1	0.0	85.9	31.7	0.0	68.3
2	21.9	0.0	78.1	47.4	0.0	52.6
3	41.6	0.0	58.4	67.2	0.0	32.8
4	68.8	0.0	31.2	94.4	0.0	5.6
5	85.1	0.0	14.9	96.7	0.0	3.2
6	91.1	0.0	8.9	98.6	0.0	1.4
7	93.7	0.0	6.3	99.4	0.3	0.3
8	94.4	0.0	5.6	99.4	0.3	0.3
9	96.7	0.0	3.3	99.3	0.7	0.0
10	97.0	0.0	3.0			

[a]After removal from container. 0 = day removed.

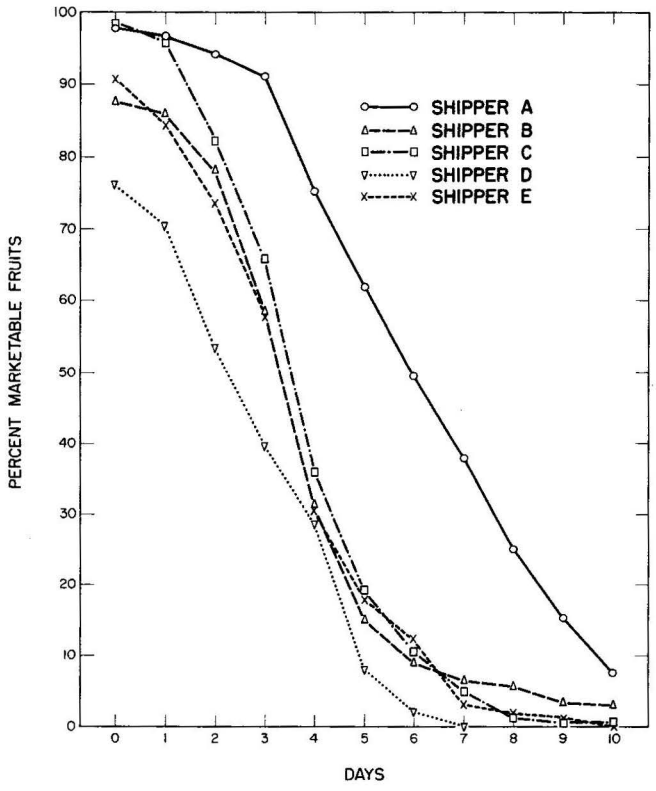

Figure 1. Daily percent marketable fruits of ¼-ripe papayas of all shippers after removal from container.

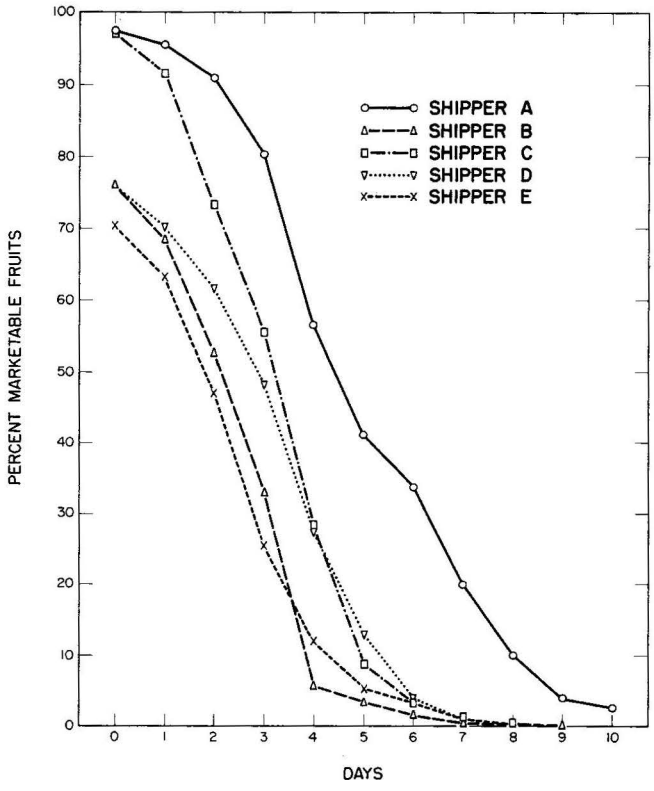

Figure 2. Daily percent marketable fruits of ½-ripe papayas of all shippers after removal from container.

Table 5. Daily percent marketable Shipper C papayas after simulated container-shipping, as determined by incidence of storage decay and overripening (data based on total number of fruits in each lot)

	1/4-ripe fruit			1/2-ripe fruit		
Days[a]	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable
0	1.7	0.0	98.3	2.9	0.0	97.1
1	4.2	0.0	95.8	8.3	0.0	91.7
2	17.9	0.0	82.1	26.7	0.0	73.3
3	34.2	0.0	65.8	44.6	0.0	55.4
4	64.2	0.0	35.8	71.7	0.0	28.3
5	80.8	0.0	19.2	91.3	0.0	8.7
6	89.6	0.0	10.4	96.7	0.0	3.3
7	95.0	0.0	5.0	98.8	0.0	1.2
8	98.4	0.4	1.2	99.6	0.0	0.4
9	99.2	0.4	0.4	100.0	0.0	0.0
10	99.2	0.4	0.4			

[a]After removal from container. 0 = day removed.

Table 6. Daily percent marketable Shipper D papayas after simulated container-shipping, as determined by incidence of storage decay and overripening (data based on total number of fruits in each lot)

Days[a]	1/4-ripe fruit			1/2-ripe fruit			3/4-ripe fruit		
	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable
0	23.8	0.0	76.2	23.9	0.0	76.1	23.5	0.0	76.5
1	29.7	0.0	70.3	30.0	0.0	70.0	23.5	0.0	76.5
2	46.5	0.0	53.5	38.6	0.0	61.4	52.9	0.0	47.1
3	60.4	0.0	39.6	51.8	0.0	48.2	78.4	0.0	21.6
4	71.3	0.0	28.7	72.5	0.0	27.5	92.1	0.0	7.9
5	92.1	0.0	7.9	87.1	0.0	12.9	96.1	0.0	3.9
6	98.0	0.0	2.0	96.1	0.0	3.9	100.0	0.0	0.0
7	100.0	0.0	0.0	98.5	0.4	1.0			
8				98.9	1.1	0.0			

[a]After removal from container. 0 = day removed.

Table 7. Daily percent marketable Shipper E papayas after simulated container-shipping, as determined by incidence of storage decay and overripening (data based on total number of fruits in each lot)

Days[a]	1/4-ripe fruit			1/2-ripe fruit		
	Decayed	Overripe	Marketable	Decayed	Overripe	Marketable
0	9.3	0.0	90.7	29.5	0.0	70.5
1	15.5	0.0	84.5	36.9	0.0	63.1
2	26.4	0.0	73.6	53.1	0.0	46.9
3	42.2	0.0	57.8	74.5	0.0	25.5
4	69.4	0.0	30.6	88.2	0.0	11.8
5	82.2	0.0	17.8	94.8	0.0	5.2
6	88.0	0.0	12.0	96.7	0.0	3.3
7	95.7	1.2	3.1	97.8	1.8	0.4
8	96.5	1.9	1.6	98.2	1.8	0.0
9	96.9	1.9	1.2			
10	98.1	1.9	0.0			

[a]After removal from container. 0 = day removed.

When the data are presented as shelf life--that is, average number of marketable days (Table 8)--the ratings for each shipper's papayas, given in the preceding paragraph, were more apparent. Also, except for Shipper D papayas, in which the shelf life was similar for the three initial stages of ripeness, the 1/4-ripe fruits had better shelf life than the 1/2-ripe fruits (Table 8). The effect of initial degree of ripeness on shelf life is also seen in the percentage of daily marketable fruits, shown in Figures 3, 4, 5, 6, and 7.

The effect of varying number of days of precooling the fruits prior to storage in the container, on daily percentage of marketable fruits and average number of days of shelf life, was determined for Shipper A papayas, which had the greatest number of precooling periods (1, 2, 5, 6, and 7 days). The daily percentage of marketable fruits for the 1/4-ripe fruits was similar for all precooling periods, but this was not the case for the 1/2-ripe fruits (Table 9). This relationship between marketability and precooling period is also seen in the shelf life. In the 1/4-ripe lot, the average shelf life was 6 to 7 days for the five cooling periods, with no statistical significance in the difference among the means of the cooling periods (Table 10). In the 1/2-ripe lot, however, probably because of variable stages of ripeness, fruits precooled for 1, 6, and 7 days had equally and significantly greater shelf life than fruits precooled for 2 or 5 days (equal to each other). In fruits precooled for 1, 2, or 5 days, the shelf life of the 1/4-ripe fruits was significantly greater than that of the 1/2-ripe fruits, but in fruits precooled for 6 or 7 days, there was no difference in shelf life between the 1/4- and 1/2-ripe fruits (Table 10).

Table 8. Shelf life of papayas of all shippers after removal from container (data based on total number of fruits in each lot)

Shipper	Average number of marketable days[a]		
	1/4-ripe fruit	1/2-ripe fruit	3/4-ripe fruit[b]
A[c]	6.5 C;b	5.3 D;a	
B[c]	3.8 B;b	2.4 A;a	
C[c]	4.1 B;b	3.6 C;a	
D	2.8 A;a	3.0 B;a	2.3 a
E	3.7 B;b	2.3 A;a	

[a]Letters following the number of marketable days are used to compare means. Means with different letters are significantly different from each other. Capital letters are used to compare means in the columns (vertical comparisons) and small letters are used to make horizontal comparisons between columns.

[b]Extra cartons supplied by one shipper.

[c]Fruits that were still marketable after the 10-day storage period were assumed to have another day of salable life in calculating the shelf life. In the Shipper A lot, 7.5% of the 1/4-ripe fruits and 2.5% of the 1/2-ripe fruits were marketable after 10 days, and, in the 1/4-ripe fruits, 3.0% and 0.4% of the Shipper B lot and Shipper C lot, respectively, were marketable.

Table 9. Daily percent marketable 1/4- and 1/2-ripe Shipper A papayas, precooled for various periods prior to storage in container, as determined by incidence of storage decay and overripening after removal from container (data based on total number of fruits in each lot)

Days[a]	Precooling period (days)									
	1		2		5		6		7	
	1/4-ripe	1/2-ripe	1/4-ripe	1/2-ripe	1/4-ripe	1/2-ripe	1/4-ripe	1/2-ripe	1/4-ripe	1/2-ripe
0	97.2	100.0	100.0	100.0	94.9	91.7	98.6	97.2	97.2	98.6
1	97.2	98.6	98.6	98.6	93.2	86.1	97.2	97.2	95.8	97.2
2	97.2	98.6	98.6	94.4	88.1	82.0	93.1	91.7	93.1	87.5
3	95.8	93.1	98.6	75.0	83.1	66.7	90.3	90.3	86.1	76.4
4	87.5	79.2	80.6	34.7	69.5	33.3	72.2	80.6	65.3	54.2
5	77.8	63.9	59.7	20.8	52.5	20.8	55.6	57.0	61.1	43.1
6	65.3	54.2	45.8	16.7	44.1	18.1	38.9	44.4	52.8	34.7
7	48.6	23.6	30.8	7.0	30.5	9.7	37.5	32.0	40.3	26.4
8	23.6	8.3	20.8	0.0	23.7	4.2	26.4	18.1	30.6	19.4
9	11.1	0.0	9.7		18.6	1.4	18.1	7.0	20.8	11.1
10	1.4		7.0		6.8	0.0	11.1	4.2	12.5	8.3

[a]After removal from container. 0 = day removed.

Table 10. Effect of precooling prior to storage in container on shelf life of Shipper A papayas after removal from container (based on total number of fruits in each lot)

Precooling period (days)	Average number of marketable days[a]	
	1/4-ripe fruit[b]	1/2-ripe fruit[b]
1	7.0 A;b	6.2 B;a
2	6.5 A;b	4.5 A;a
5	6.0 A;b	4.1 A;a
6	6.5 A;a	6.5 B;a
7	6.6 A;a	5.6 B;a

[a]Letters following the number of marketable days are used to compare means. Means with different letters are significantly different from each other. Capital letters are used to compare means in the columns (vertical comparison), and small letters are used to make horizontal comparisons between columns.

[b]In the 1/4-ripe lot, the percentage of salable fruits at the end of the 10-day storage period was as follows for fruits precooled for 1, 2, 5, 6, and 7 days, respectively: 1.4, 6.9, 6.8, 11.1, and 12.5. In the 1/2-ripe lot, the percentage for the same precooling periods was, respectively: 0, 0, 0, 4.2, and 8.3. The salable fruits were assumed to have another day of marketable life in calculating the shelf life.

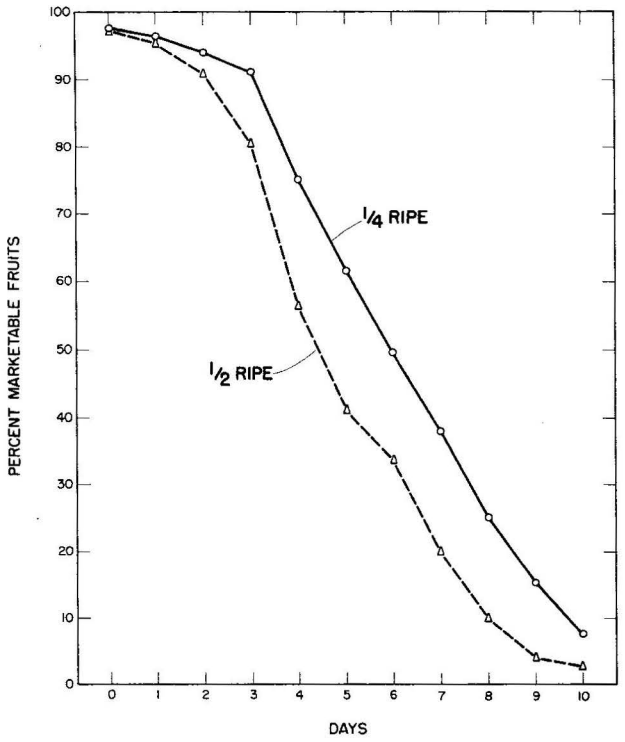

Figure 3. Daily percent marketable fruits of ¼- and ½-ripe Shipper A papayas after removal from container.

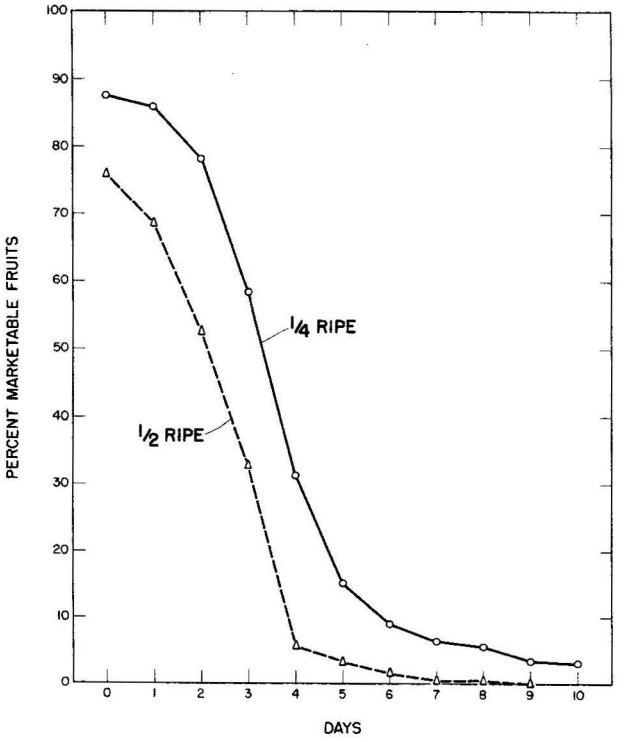

Figure 4. Daily percent marketable fruits of ¼- and ½-ripe Shipper B papayas after removal from container.

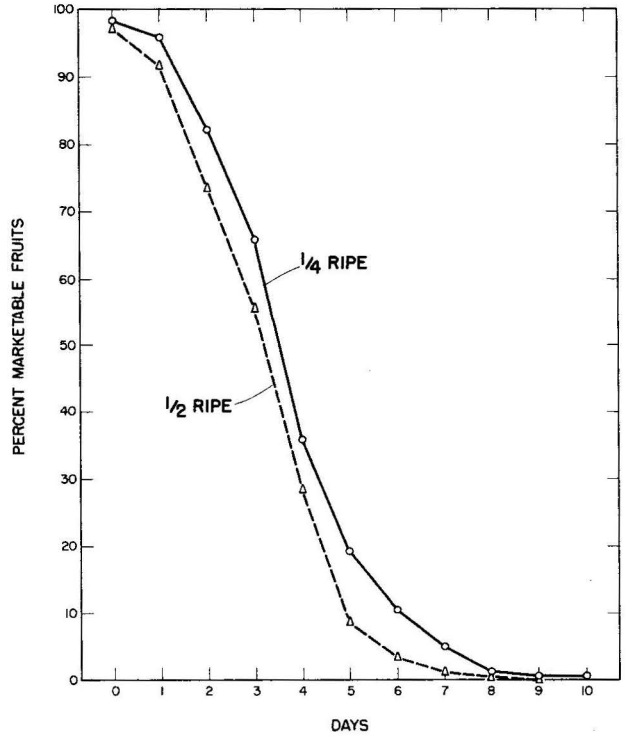

Figure 5. Daily percent marketable fruits of ¼- and ½-ripe Shipper C papayas after removal from container.

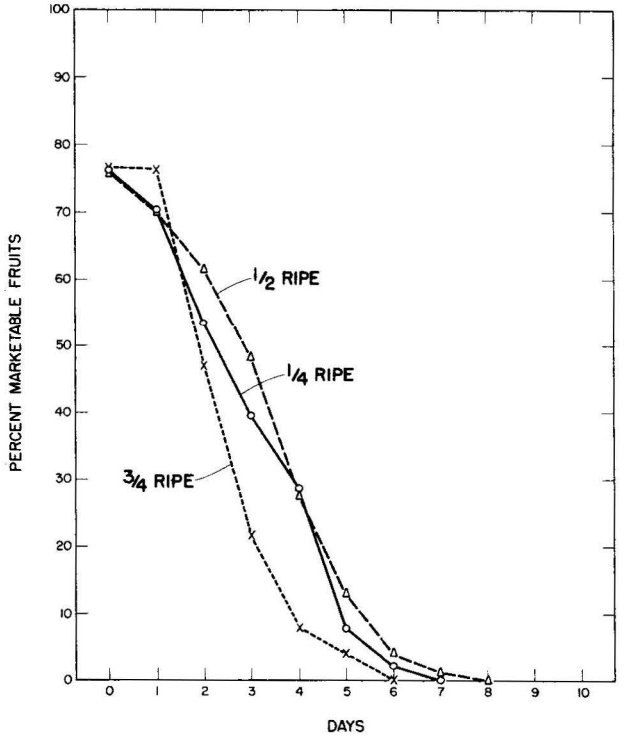

Figure 6. Daily percent marketable fruits of ¼-, ½-, and ¾-ripe Shipper D papayas after removal from container.

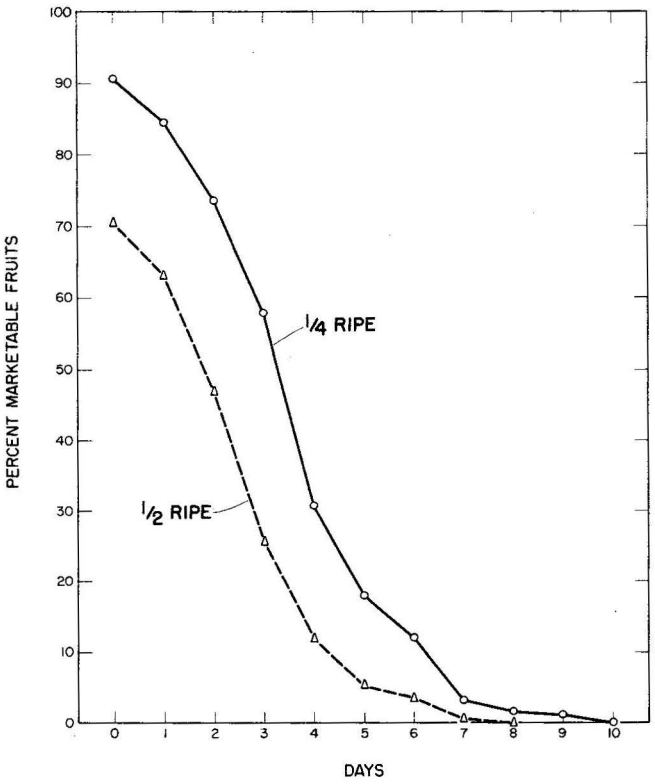

Figure 7. Daily percent marketable fruits of ¼- and ½-ripe Shipper E papayas after removal from container.

DISCUSSION

The papayas from the different sources had variable marketability and shelf life. Assuming that the degree of ripeness and quality of the papayas of the five shippers were similar when harvested, this variability probably cannot be attributed to the different packing materials used (Table 1) because the carton and fruit temperatures were similar, regardless of the type of packing material used. Judging by the performance of Shipper A papayas, days of precooling from 1 to 7 days prior to installing in the container apparently had only a minor influence on the eventual shelf life. The most important factor that determined the salable life of the fruits was treatment prior to precooling (Table 2). A good relationship exists between treatment and shelf life. In general, Shippers A and C, who used the standard disinfestation treatment (hot water + 1/2 lb EDB), had papayas with the greatest shelf life (Table 8). Shipper E papayas were also subjected to the same treatment, but their shelf life was inferior to that of Shippers A and C, probably because of the age (14 days) of the fruits when installed in the container (Table 2). However, shelf life of Shipper E papayas was equal to that of Shipper B papayas, whose shelf life was shortened by the poor control of decay by vapor heat that was substituted for hot water treatment (Tables 4, 8). In general, Shipper D papayas, which were not treated with either hot water or vapor heat, had the lowest shelf life (Table 6) because decay was not controlled.

The importance of decay control is emphasized in these results, and, although the actual temperatures of the hot water used by the shippers are not available, based on previous experience, decay control would have been better had the water bath been maintained close to 120°F. Nevertheless, the effectiveness of the hot water treatment, which was developed for papayas in 1952 (Akamine and Arisumi, 1953; Akamine, 1967) was well demonstrated in this simulated-shipping experiment, as was also the case in previous shipping trials in which the surface shipment of Hawaii papayas in refrigerated containers was found to be practical (Akamine et al., 1963).

The simulated shipping period in this experiment was about twice the actual, direct, shipping time from Hawaii to the Mainland, so the data clearly demonstrate the feasibility of shipping fresh papayas from Hawaii to the United States West Coast by marine transportation, provided that hot water is properly used to control storage decay. Furthermore, the possibility of shipping Hawaii papayas to more distant markets, such as Japan, is indicated.

RECOMMENDATIONS

Based on the results of this study and previous studies, the following recommendations are made for the shipping of fresh Hawaii papayas in refrigerated containers to the West Coast of the United States Mainland.

1. Papayas of export grade should be harvested when 1/4- to 1/2-ripe and, rapidly, successively treated with hot water at 120°F for 20 minutes, cooled with tap water for 20 minutes, and fumigated with EDB at a dose of 1/2 pound per 1000 cubic feet space for 2 hours (required standard disinfestation treatment for export fruit).

2. The treated papayas should then be packed in commercial cardboard cartons. The current harvesting, treating, packaging, and shipping schedules will necessitate the holding of packaged fruits at least a day before loading them in a container. Fruits should be precooled for no longer than 1 week at about 50°F during this holding period.

3. The precooled papayas should be transferred into the refrigerated container as rapidly as possible to minimize the rise in temperature of the fruit. The cartons should be loaded in such a manner (spaces between cartons, stacking, and so on) that adequate air movement within the container is assured. The temperature of the container should be maintained at about 50°F throughout the transit period.

OTHER CONSIDERATIONS

1. The commercial carton currently used for shipping papayas by air is inadequate for container shipping. It is not strong enough to withstand the amount of stacking necessary to fill the container; furthermore, because packing materials are used and the carton must be sealed, papayas are not exposed to the free circulation of air that is necessary for uniform distribution of temperature within the cartons. Therefore, a standard carton that provides adequate strength and durability when stacked and good ventilation should be designed.

2. Openings in a carton would provide ventilation for the papayas, but this violates the quarantine requirement of a sealed carton. This requirement could be met by using the entire shipping container as a sealed unit. It is thus recommended that papayas in a ventilated carton be loaded into the container immediately after treating and packing at the packing facilities of the shipper. The container would then be sealed and certified for shipping by the quarantine inspector, and this would also eliminate precooling the fruit in a separate cold room.

3. In order to facilitate loading of the container, cartons should be loaded in pallet lots with forklifts or by other mechanical means.

4. In order to minimize infection of papayas by decay organisms in transit, the interior of the container should be cleaned and disinfected periodically with sodium hypochlorite or other suitable germicide.

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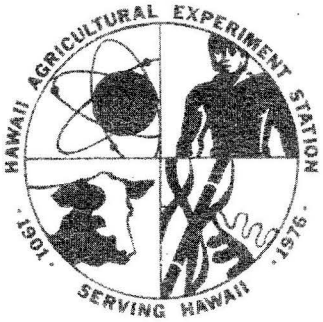

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